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Next-Generation Communications

Jim has given you a thorough picture of the types of communication changes the military will embrace in the next several years. As he explained, these programs will increase the military's dependence on access to the RF spectrum.

Access to the spectrum is not new, of course, and communication devices are becoming much better at accessing it. However, the spectrum suitable for wireless, mobile communications is finite and bounded by both physics and technology. In particular, the spectrum from 200 MHz to 3 GHz is needed, not only by military systems, but also by increasing numbers of new civil devices and services. Cell phones, wireless e-mail, digital audio, high definition TV—you name it—all of them are competing for the same spectrum the military needs for its most advanced tools. The result is a difficult—and I'd say unsustainable—situation. At the very moment the Department of Defense is relying more on wireless information systems, it has to address the growing nonmilitary spectrum demand. As you can see, the military has only a small portion of this key spectrum.

What I'm describing is just the situation in the United States; overseas, the problem is even worse. When we operate in another country, whether in war or peace, our forces are always subject to the host nation national sovereignty and regional spectrum usage patterns. This is true in both friendly and hostile environments. Abroad, there is no guarantee that required spectrum is available. Even if it is available, the existing management process to locate and assign frequencies in advance is lengthy, difficult, and uncertain—unsupportive of the rapid response capability we are developing.

It is easy to imagine a worst-case scenario. We have the most sophisticated and highly flexible forces and C31 capabilities. Yet the military's capabilities may prove useless simply because the spectrum is so constrained.

Next-Generation Communications is focused precisely at this problem. Because XG not only promotes more effective spectrum use but also effectively changes the rules of the game, we believe it represents the next generation of communications. XG, as we call it, is premised on a notion that challenges conventional wisdom about the spectrum. In most discussions, it is assumed that spectrum demand overwhelms the fixed supply. But we look at the spectrum in a different way. What we see is a dynamic system, one in which spectrum use changes at each instant, as you can see in this real-world spectrum usage measurement. According to our initial measurements, on average, only 2 percent of the spectrum is actually in use in the United States at any given moment, even though all spectrum is allocated. That percentage may be even lower in foreign countries.

If this is true, the key technology question becomes whether the unused spectrum can be exploited for our purposes, while ensuring that other systems don't interfere with us, and that we don't interfere with them. To answer that question, the XG Program is developing four key technologies.

The first is to embed low-power and compact spectrum sensing capability within XG-enabled systems. Low power use is key to highly mobile and proliferated applications

Second, we need to characterize the spectrum use by classifying the signals we sense in order to understand how to coexist with them.

- Is it being used for military systems?
- Television?
- Which cellular technology is it using?
- Is there frequency, time, or code space available to share?

For both of these technologies, we are leveraging electronic warfare programs such as Wolfpack, which you just heard Jim describe.

The third XG technology we are developing is the ability to react to the other spectrum users through selection and coordination of frequencies, bandwidths, spreading codes, and so forth. The goal is to make the XG system operate without interference from or to other users. We will develop media access controls that support a range of physical waveforms and best exploit the features of each. Others may extend this work and develop tailoring specific to their physical layer designs.

Later in the program, we will look at XG-optimized waveforms that can best exploit XG capabilities through noncontiguous waveforms, highly spread water-filling underneath other signals, and other adaptive waveform technologies.

Finally, XG needs to adapt to changes in spectrum use by developing, coordinating, and disseminating new spectrum planning. These changes could be caused by radar scanning the region, new mobile devices entering the area, or the XG network moving and encountering a new environment.

By integrating the frequency assignment function into the network operations, we can develop a battlefield where networks detect, coordinate, and manage spectrum using common protocols. They will do this automatically and autonomously. Because the networks don't depend on pre-assigned spectrum, they will greatly reduce the amount of spectrum needed to operate. I believe it will change the nature of battlefield communications.

What we envision with XG is nothing less than a new generation of intelligent, situationally aware, network radio—a network radio that takes on more and more of the resource management within itself. Imagine for a moment a modern battlefield—vehicles, troops, special ops, radar, sensors, remote devices. Today, there might be as many as 8,000 separate networks simultaneously operating, each of them needing its own, individually assigned spectrum.

With XG, we will have a generic wireless Internet that can be accessed simply by turning on a radio or communications device. The network detects other systems operating in the region. It automatically places and coordinates the network or sensor devices to appropriate frequencies. As forces move or other participants join, the XG system automatically adapts. As you can see, when two mobile networks overlap, one automatically and seamlessly shifts to a new frequency.

Troops, vehicles, radar, radios—all these components of modern warfare will seamlessly organize their use of spectrum. For example, when a radar illuminates the mobile network, the network adapts its spectrum usage to avoid the radar system. There is no need for extensive preplanning. The more RF assets we can pool, the more optimal a solution we can achieve, so this program addresses sensor as well as communications systems.

How quickly do we see this development? We imagine XG will mature through a series of stages. At first, our emphasis will be on intranetworking capability, focused mostly on better managing spectrum use within homogenous networks. It will be ideal for emerging technology such as our Small Unit Operations Situation Awareness System, or SUO SAS. As the technology develops and more XG applications are deployed, it will become indispensable for internetworking coordination.

We also envision that sensor systems could participate in spectrum planning with an XG network. This is particularly important in scenarios where frequency and spatially agile radars limit prediction by XG participants. Multiple networks would be able to coordinate and share spectrum use both with U.S. systems and with the networks of allies, coalition partners, or even local civilian users.

Let me briefly address the process that DARPA will use to pursue the XG Program. XG is a 5-year program. It will rely on a Government- and industry-based development path. During the first year, we will be focusing largely on the measurement and characterization of existing spectrum use. Recall those are the first two processes in an XG implementation, and further work in this area will continue throughout the program. During this part of the program, we will be looking at military exercises, battlefield, urban, and rural environments. We will verify that the opportunities we project do exist and better understand the capabilities required to exploit them.

For 2002 and 2003, we have a PRDA out of the Sensors Directorate of Air Force Rome Laboratories that is focused on resolving high-risk XG issues.

In 2004, we will develop the XG protocols and then an implementation of them within a military system. Although our implementation will be specific to DoD, we intend to develop a MAC layer design that is extensible to address nonmilitary uses.

You might ask, "Why are we so interested in ensuring that XG is usable by the civilian community?" We see three important benefits of this for DoD. First, if the U.S. military is going to achieve full benefit of the XG technology overseas, we need to have a favorable international and national regulatory environment. Clearly, civilian advocacy would be more effective in achieving this than military advocacy alone. Second, we believe XG can reduce pressures to reallocate military spectrum for civilian use by affording greater civilian access to existing spectrum allocations. Finally, commercial use would bring with it high volume production that can reduce the cost of military applications.

As all of you know, DARPA does not develop, much less set, policy. Still, it is impossible not to appreciate the policy implications of XG technology. Once developed, XG will enable enormous changes in the way the United States and other nations manage their spectrum resources.

Consider this: existing technology has forced us to think about spectrum allocation strictly as a regulatory problem. Spectrum is assigned to a single owner for a specific purpose, throughout the United States. Although our military and civilian uses vary greatly throughout the United States, we have the same spectrum allocation in Manhattan as we do over the Mohave Desert. The dynamics of how that spectrum is used, or how it might be shared, have not been seriously considered.

The result of XG will be not just be a more efficient system; it will be a fundamentally different one. In the world of XG, spectrum can be shared with non-XG legacy systems and coordinated with other XG systems. The existing spectrum user risks nothing from sharing its spectrum. And because XG is a dynamic system, adjusting itself to the spectrum available, it allows the priority user to adapt spectrum use as circumstances warrant.

That type of flexibility will be a major advantage for the Department of Defense. It will be able to meet the significantly increased demand for spectrum-dependent systems with less fear of interference or conflict with other systems. DoD will be able deploy systems without the months of meticulous planning and spectrum assignment required today. In fact, while XG will prove to be indispensable to military applications, it has very significant advantages in civilian use. Wireless, autonomous communications networks will not only transform battlefield radios and radar, but also can transform similarly the next generation of sophisticated cell phones, digital devices, and mobile communicators that are flooding the public markets.

With the appropriate regulatory framework, commercial products that utilize XG will trade additional complexity in the radio for an opportunity to access an order of magnitude more spectrum. For that reason, we are designing our media access control layer protocols and controls so that they support other spectrum users and concepts and will ensure the XG standard is in the public domain.

The box we typically use to display spectrum allocation was a function of decades-old technology and regulatory approaches. It is full of "property lines" demarcating preset allocations. Every box represented preset limits with no flexibility. XG doesn't just change the partitions; it erases them. It replaces a static regulatory framework with technology that is dynamic, intelligent, and completely independent.

In the world of XG, the spectrum can be an open space, without fixed limits, and colors. It can make the allocation chart all white